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SCHOENOPLECTIELLA ×MAGRATHII (CYPERACEAE), A NEW INTERSPECIFIC HYBRID BETWEEN *S. HALLII* AND *S. SAXIMONTANA* FROM OKLAHOMA

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ABSTRACT

Schoenoplectiella ×magrathii Smith & McKenzie is described. Morphological and DNA evidence indicate that it is a hybrid between *S. hallii* and *S. saximontana*. Hybrid individuals at two localities in southwestern Oklahoma (Comanche County) show great morphological variability and range from being 96% infertile to producing an array of fertile achenes that vary in shape, including either 2- or 3-sided achenes that are typical of one parent or the other, while some achenes are asymmetrical or with a prominent bump on the adaxial surface. A photo of the holotype is provided and details of achene variation are illustrated.

KEY WORDS: *Schoenoplectiella*, *Schoenoplectus*, new hybrid, conservation, Oklahoma

Schoenoplectiella hallii (A. Gray) Lye and *S. saximontana* (Fernald) Lye are sedge species that were once thought to be allopatric, with *S. hallii* occurring primarily in the Midwest and eastern U.S. and *S. saximontana* largely confined to the western portions of the country (Gleason & Cronquist 1991; Beatty et al. 2004). *Schoenoplectiella hallii* has a global ranking of G2/G3 (imperiled/vulnerable; NatureServe 2012). It is listed as "critically imperiled" in eight of the 11 states in which it occurs, "imperiled" in two, and "vulnerable" in one. Herbarium records indicate that it had been reported from Georgia and Massachusetts prior to 1981 (McKenzie et al. 2007), but those populations are likely extirpated (NatureServe 2012; McKenzie et al. 2007). *Schoenoplectiella saximontana* has a global ranking of G5 (secure; NatureServe 2012), but it is listed as "critically imperiled" in British Columbia as well as in 7 of the 11 states where it occurs. It has been reported from eight states in Mexico (González Elizondo et al. 2008). Throughout its range, *S. saximontana* is considered to be an uncommon species whose distribution is scattered (Smith 2002).

Schoenoplectiella hallii and *S. saximontana* are obligate wetland species that have similar habitat requirements — most often sandy, rocky or gravelly soil, occasionally clay, around the margins of ponds, ditches and swales with fluctuating water levels, and a scarcity of other plants as competitors (Smith 2002; McKenzie et al. 2007). They most commonly complete their life cycle as annuals, but short-lived perennials have been reported from Mexico (González Elizondo et al. 2008) and Texas (O'Kennon & McLemore 2004). Dispersal within and among sites is thought to be facilitated by migrating waterfowl and a variety of large mammals, including elk, cattle, bison, and feral pigs (McClain et al. 1997; Magrath 2002; McKenzie et al. 2007; Smith & McKenzie 2011).

Both species have 2–3 small basal leaves and tufted stems 5–40 cm long with small, inconspicuous rhizomes (Yatskievych 1999; Smith 2002). The species are amphicarpic, with numerous spikelets on aerial stems containing perfect flowers and pistillate flowers enclosed in a leaf

sheath at the plant base (Yatskievych 1999; Smith 2002). It is difficult to distinguish between the species based on vegetative characters, but the spikelet achenes of *Schoenoplectiella hallii* are 2-sided and flowers have 2-lobed styles (Smith 2002; Smith et al. 2006), whereas spikelet achenes of *S. saximontana* are 3-sided and flowers have 3-lobed styles (Smith 2002). Achenes of both species have transverse ridging, but Magrath (2002) and Smith and McKenzie (2011) reported that the ridges on *S. saximontana* were "winged" while those on *S. hallii* were smooth.

Five states (Kansas, Missouri, Nebraska, Oklahoma and Texas) have populations of both species (NatureServe 2012). Oklahoma (Magrath 2002), Kansas (C. Freeman, pers. comm. 2006), Texas (R. O'Kennon, pers. comm. 2007) and Nebraska (R. Steinhauer, pers. comm. 2012) are known to have sites with mixed populations, while Missouri apparently does not. Although the mixed population site in Kansas has not been re-confirmed since 1997 (Freeman, pers. comm. 2006), *Schoenoplectiella hallii* is known to have a long-lived seed bank and may re-emerge under suitable environmental conditions (Baskin et al. 2003; Smith et al. 2006; McKenzie et al. 2007). The two species have similar habitat requirements and hard-surfaced achenes of similar size (Yatskievych 1999; Smith 2002; Smith & McKenzie 2011), which suggests that the seed bank potential of *S. saximontana* is likely to be long-lived as well. Since 1999, numerous new populations of *S. hallii* have been reported in Nebraska, and a large population containing both species also was discovered there in 2010 (Steinhauer, pers. comm.). In Oklahoma *S. saximontana* occurs in eight counties, but it is known in the same populations with *S. hallii* in only Comanche County (Oklahoma Vascular Plant Database 2012). Although *Schoenoplectiella saximontana* has been known from a number of populations in south Texas for many years, the presence of *S. hallii* in the LBJ Grasslands in North Texas was first reported by O'Kennon and McLemore in 2004, and both species were discovered at Rhodes Lake, Decatur County, in 2007 (O'Kennon, pers. comm. 2012). As it is less than 120 miles from Rhodes Lake to the populations in Comanche County, Oklahoma, it is plausible that migrating waterfowl could have dispersed seeds from these earlier-established populations to north Texas. Additional *S. hallii* and *S. saximontana* sites have been discovered on the LBJ Grasslands recently, some individuals having both 2- and 3-sided achenes (O'Kennon, pers. comm. 2012). In addition, *S. saximontana* populations containing apparent hybrids were found at Enchanted Rock State Natural Area in south-central Texas in 2012 (O'Kennon, pers. comm.).

In August 2001, following the previous year's discovery by Dr. Lawrence Magrath of mixed populations of *Schoenoplectiella hallii* and *S. saximontana* on the Wichita Mountains Wildlife Refuge (WMWR), Comanche County, Oklahoma (Magrath 2002), M. Smith and P. Mettler-Cherry re-examined the sites. During the survey, Smith noted the occasional individual containing achenes that were 2-sided like those of *S. hallii*, except the usually flat or concave side contained a conspicuous bump, while other achenes had ridges with the "winged" appearance of *S. saximontana* (Smith & McKenzie 2011). Often, an individual had both 2- and 3-sided achenes, some with and some without "winged" ridges. Other individuals produced only a few viable-looking achenes, with the majority of spikelets bearing a preponderance of abortive achenes. Smith interpreted these anomalies as suggestive of hybridization between *S. hallii* and *S. saximontana.*

In 2002, voucher specimens were collected at WMWR and sent to Dr. Galen Smith and Dr. Alfred E. Schuyler, who independently confirmed that *McKenzie 2028* appeared to be of hybrid origin (specimens deposited at PH, OKL, and WIS). During subsequent surveys by the authors from 2003 to 2010, individuals of the putative hybrid were collected from two sites on the WMWR and from two sites on the adjacent Fort Sill Military Reservation (FSMR) (Smith & McKenzie 2011). Plants from these sites, examined using three ISSR primers, confirmed that species-specific markers were present in each parental species and that the putative hybrids contained markers from both (Esselman et al. 2012). Recent work using flow cytometry indicates that the hybrids have a DNA content intermediate between that of the parental species (E. Esselman, pers. comm. 2012). Given the

preponderance of evidence documenting the presence of a hybrid cross between *S. hallii* and *S. saximontana*, it is appropriate to proceed with the formal recognition of the hybrid.

SCHOENOPLECTIELLA ×MAGRATHII Smith & McKenzie, **hybrid nov. TYPE: USA. Oklahoma.** Comanche County: Wichita Mountains Wildlife Refuge, Medicine Tank (34.797814°; -98.723846°), 14 Oct, 2007, *P.M. McKenzie 2317* (holotype, MO, Fig. 1; isotypes: ANHC, MICH, MO, UMO).

Differences between the putative hybrids and parents (*Schoenoplectiella hallii* and *S. saximontana*) range from subtle to more definitive (Table 1). Culms and inflorescence spikelets of hybrids can be noticeably longer than those of parental species (Table 1, Fig. 3); individuals may have flowers with styles either or both 2-fid or 3-fid; achenes may be fertile, abortive (Fig. 2) or malformed (Fig. 2). Fertile achenes are variously 2-sided (plano-convex with adaxial surface flat or concave and abaxial surface convex), 3-sided (equilaterally trigonous), intermediate with adaxial surface concave and abaxial surface slightly rounded to pointed or variously convex or malformed (prominent bump on adaxial surface) (Fig. 2). Achene surface ridges may occur with or without sharply defined wings. In mixed populations, hybrid plants may be conspicuously taller with longer spikelets than *S. hallii* and *S. saximontana*. These larger plants typically have orange-brown scales at maturity and a high percentage of abortive achenes (Fig. 3). Plant description and measurements here for the hybrid are similar to those provided for the putative parents (Yatskievych 1999).

Table 1. Distinguishing characters of *Schoenoplectiella ×magrathii* relative to *S. hallii* and *S. saximontana*. All values as in Yatskievych (1999) except as indicated by superscripts

Character	***S. hallii***	***S. ×magrathii***	***S. saximontana***
Culm length	4 – 35 cm	4 – 50 cm[1]	4 – 40 cm
Involucral bract length	3 – 10 cm	1.3 – 15 cm[1]	3 – 16 cm
Spikelet length	5 – 13 mm	3.3 – 38 mm[1]	5 – 16 cm
Spikelet number	1 – 5	1 - 15[1]	1 – 10
Spikelet achene length	1.3 – 1.7 mm	0.9 – 1.9 mm[1]	1.3 – 1.7 mm
Fertility of spikelet achenes	100%[2]	4 – 50%[1,2]	96%[2]
Spikelet achene shape	2-sided	Misshapen, 2- or 3-sided[3]	3-sided
Winged achene ridges	Absent	Present or absent[3]	Present
Spikelet style lobes	2	2 or 3[3]	3

[1]Measures taken from holotype, isotype & paratypes
[2]Smith et al. 2004
[3]Smith & McKenzie 2011

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HOLOTYPE OF:
Schoenoplectiella ×magrathii F.M. Sm. & P.M. McKenzie
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MISSOURI BOTANICAL GARDEN
PLANTS OF OKLAHOMA
Schoenoplectus hallii (A.Gray) S.G. Smith X
Schoenoplectus saximontanus (Fernald) J. Raynal
Commanche County: Wichita Mts. National Refuge, west of Lawton, OK.- Medicine Tank pond; Longitude: 98.72; Latitude: 34.80. Common on exposed mud along west end of pond. In association with S. hallii and S. saximontanus. Same collection locality as P.M. McKenzie 2028 of 28 July 2002. Hybrids typically more robust than either parent and with longer inflorescences that are conspicuously brownish orange. Abortive, 2-sided and 3-sided achenes all present in most inflorescences.
Paul M. McKenzie 2317
with Marian Smith & Nancy Parker
14 Oct 2007

Figure 1. Holotype of *Schoenoplectiella ×magrathii* Smith & McKenzie.

Additional specimens examined: **Oklahoma**. Comanche Co.: Wichita Mountains Wildlife Refuge, Medicine Tank: 28 Jul 2002, *McKenzie 2028* (PH, OKL, WIS), 18 Sep 2008, McKenzie 2351 (MO), 25 Aug 2009, *McKenzie 2393* (MO), 14 Sep 2010, McKenzie 2460 (MO); Wichita Mountains Wildlife Refuge, Quanah Parker Lake (34.716044°, -98.641223°), 26 Aug 2009, *McKenzie 2408* (MO). Fort Sill Military Reservation, Zania Pond (34.661349°; -98.626640°), 26 Aug 2009, *McKenzie 2402* (MO); Fort Sill Military Reservation, Pottawatomie Twin Pond (34.657713°; -98.641223°), 26 Aug 2009, *McKenzie 2405* (MO), 14 Sep 2010 *McKenzie 2461* (BRIT, MO, OKL).

The epithet honors the late Dr. Lawrence Magrath, who made available to us the initial report from his 2000 survey and specimens of *Schoenoplectiella hallii* and *S. saximontana* from the University of Science and Arts of Oklahoma herbarium (OCLA).

Distinguishing characteristics

Further study of a variety of hybrids from sites in Oklahoma confirmed the earlier observation that although some individual achenes had distinct morphological characteristics of one parent or the other, many were asymmetrical with a bump on the adaxial side (Fig. 2). Some plants bore a preponderance of abortive achenes (inset Fig. 3), but others had all three variations of achene structure (misshapen, 2- and 3-sided) (Fig. 3), with or without winged ridges and appeared to be mature and viable.

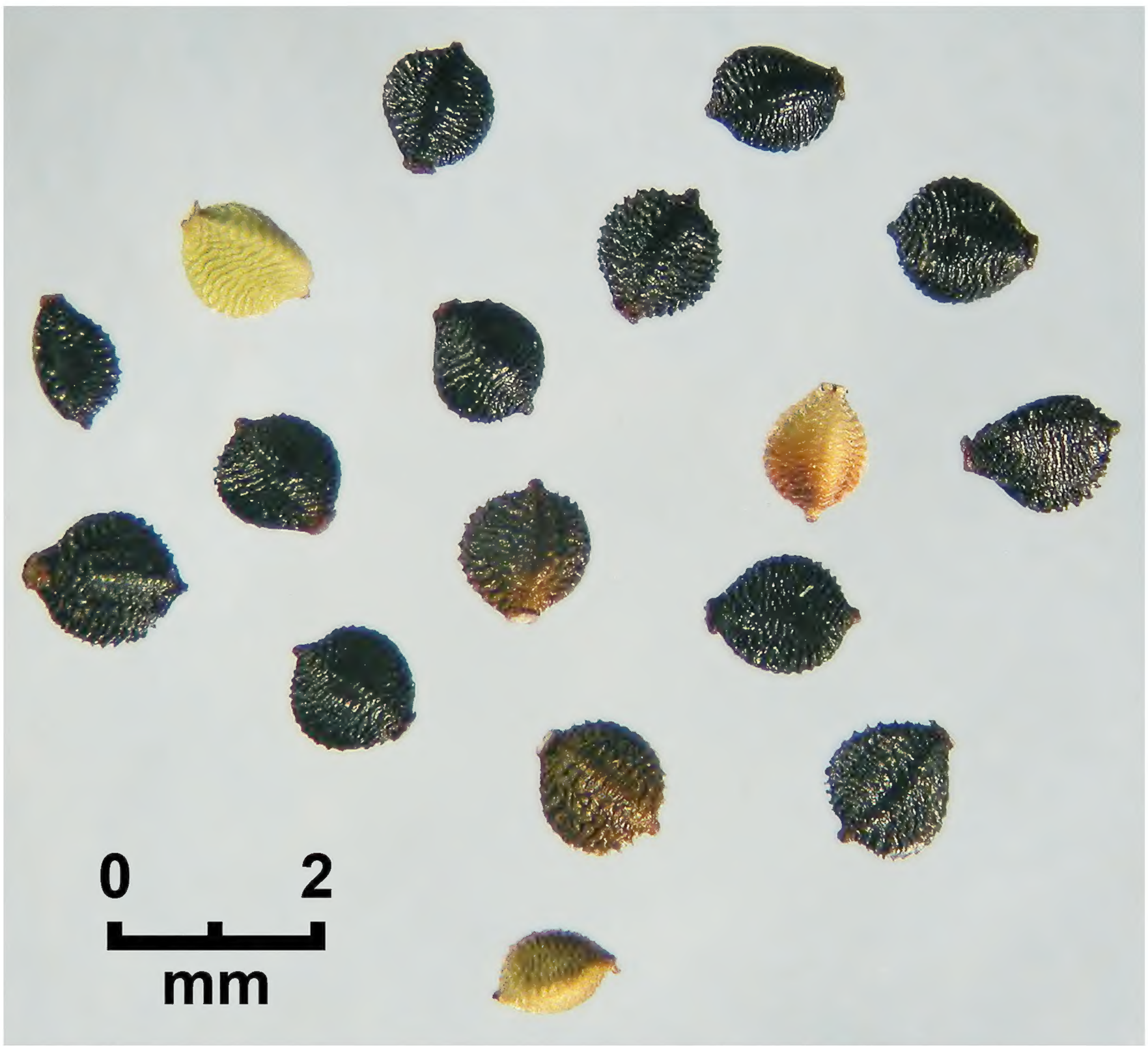

Figure 2. Example of some of the variation in achene shape in *Schoenoplectiella* ×*magrathii*.

Figure 3. Unmounted specimen of *Schoenoplectiella ×magrathii*. Inset contains abortive 3-sided achenes, one bearing a characteristic 3-fid style, produced by this individual. Approximately 4% of the achenes produced by this plant were fertile (Smith et al. 2004).

In addition to variation in achene shape, texture, and development, individual hybrids exhibited variability in style lobe-number. In 2004, Smith et al. reported that of the 56 spikelet flowers they examined, 2-lobed styles were associated with 2-sided achenes while 3-lobed styles were present on all trigonous achenes, regardless of whether they were collected from *Schoenoplectiella saximontana* or the putative hybrid. This condition appears to be common, if not universal, among the hybrids examined thus far.

Some hybrid individuals are larger and more robust compared to either parent present at the same site (e.g., as in Fig. 3). Most notably, these hybrids have large, orange-brown spikelets that often contain a high percentage of aborted achenes (inset Fig. 2). Fertile achenes can be either 2- or 3-sided, with winged ridges absent or present.

Discussion

The outstanding feature of *Schoenoplectiella* ×*magrathii* is the high degree of variability in the morphology of its achenes within and among individuals. Because a single hybrid individual may produce both 2- and 3-sided achenes, as well as misshapen or abortive ones, proper identification in the field requires a careful examination of several achenes from a variety of spikelets. Factors underlying the variability may include these: (1) widely divergent chromosome numbers of the parents (*S. hallii*, n = 11; *S. saximontana*, n = 25) (Rieseberg 2001), (2) existence of several generations in the sample population (Esselman et al. 2012), (3) movement of genes due to backcrossing of hybrids with both parent species with possible effects on achene morphology and viability (Carney et al. 2000), (4) changes in DNA due to emergence from a long-lived seed bank (Cheah & Osborne 1978; Osborne et al. 1980; McKenzie et al. 2007) or to the relatively brief period that the parents have been sympatric (Salas-Pascual et al. 1993; Smith & McKenzie 2011).

We have confirmed the presence of the new hybrid only in Oklahoma (two sites on the WMWR and two sites on the FSMR); however, the existence of mixed sites in Texas presents other opportunities for hybridization. Because the long-distance dispersal of the parental species is likely via migrating waterfowl (McClain et al. 1997; Smith & McKenzie 2011), the populations in Nebraska are likely to become increasingly mixed in the future. The same may be the case for a historical site in Kansas where both species were collected in 1997, but the locality has not been revisited to determine if *Schoenoplectiella hallii* and *S. saximontana* still co-occur (C. Morse, pers. comm. 2012). Nonetheless, it is likely that the achenes of both species occur in the seed bank if the habitat at the site has remained intact.

Hybridization among various members of the genus *Schoenoplectiella* are apparently not uncommon. Hayasaka (2012) listed 7 hybrid taxa from various parts of Asia. Smith (2002) reported a likely hybrid between *Schoenoplectiella hallii* and *S. erecta* (Poir.) Lye subsp. *raynalii* (Schuyler) Beentje from the Georgia coast. Additionally, there is a specimen at MICH and BRIT (*Lundell & Lundell 10745*!) that is also a possible hybrid between *S. saximontana* and *S. erecta* subsp. *raynalii* from a locality along the south Texas coast (Kenedy County), where *S. hallii* is not known to occur. The specimen has the elongated spikes, brownish-tan spikelet scales, and numerous abortive achenes typical of *Schoenoplectiella* ×*magrathii*.

Although *Schoenoplectiella hallii* and *S. saximontana* are currently distinct species (Young 2002), hybridization at the Oklahoma sites threatens their continued existence. As reported by Smith and McKenzie (2011), only hybrids were found at the FSMR site in 2010 where parents and hybrids were abundant in 2009. They also reported declines of both parental species at the WMWR sites since 2007, and *S. saximontana* was absent in 2010 from the Medicine Tank site (WMWR), where it was once abundant. *Schoenoplectiella saximontana* reappeared at this site in 2012, a year with unusual environmental conditions: from July–August, record hot, dry weather occurred followed by rainfall and mild temperatures in October, when the species reappeared. The unusual weather may have played a role in its emergence from the seedbank. At this site, the decline in the parental taxa and the apparent increase in number of hybrids suggest that the hybrids may outcompete either of the parental species, at least under certain environmental conditions.

Why the number of *Schoenoplectiella* hybrids appears to be increasing is unknown. Although the chromosome numbers of the parental taxa differ and many hybrid achenes examined

during observations made between 2001 and 2010 appeared to be abortive (Smith et al. 2004; Smith & McKenzie 2011), viable seeds were produced by others (Smith et al. 2004). Arnold et al. (2011) suggested that despite the low fertility of hybrid species, they are still able to produce viable gametes for successive generations. The chromosome number of *S.* ×*magrathii* is unknown, but it is possible that ploidy levels vary among generations and result in increased fertility (Soltis & Soltis 2000; Chester et al. 2012) in some of the hybrids.

Further Research

Additional surveys of *Schoenoplectiella hallii* and *S. saximontana* in Kansas, Nebraska, Oklahoma and Texas, where the two species are sympatric, are warranted. Monitoring of sites that have extant populations of *S. hallii, S. saximontana*, or *S. erecta* subsp. *raynalii* should be undertaken to look for the potential presence of the other species. In Nebraska, *S. saximontana* was documented at a site that had a large population of *S. hallii* but from a region of the state where *S. saximontana* had previously not been recorded (Steinauer, pers. comm. 2012). The increasing incidence of mixed populations throughout the Midwest in the past decade suggests that hybridization in Oklahoma may presage the development of a very large hybrid zone throughout the center of the USA. Because *S. saximontana* and *S. erecta* subsp. *raynalii* (2*n* = 10) are sympatric in some areas of southern Texas, possible hybridization between these two taxa should be evaluated, especially at sites where both species have been documented. We have observed achenes of *Schoenoplectiella* ×*magrathii* that are similar in shape to those described by Smith (2002) for *S. erecta* subsp. *raynalii*, and variations in achenes of *S. erecta* (sensu lato) contributed to the description of two species that are now synonymous with *S. erecta* subsp. *raynalii* (i.e. *Scirpus wilkensii* Schuyler and *Scirpus erismanae* Schuyler (Schuyler 1969)). The same is the case for *Scirpus bergonsii* Schuyler (Schuyler 1969) that is now placed in synonymy with *Schoenoplectiella saximontana*. In addition, the reproductive potential of *S.* ×*magrathii*, estimates of pollen viability, seed set, ploidy level, and environmental conditions conducive to germination and growth should be investigated in the near future.

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